INTEGRATED PULPWOOD AND BIOMASS HARVESTING BOISE CASCADE CANADA LTD. NEWCASTLE, N.B.

68

December 1984

CREDA PROJECT #2056

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This final report is based on a project which was financially supported by the Energy Demonstration Program. For further information on other demonstration projects funded in New Brunswick under this program, contact:

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Ce rapport final est basé sur un projet qui a reçu une aide financière du Programme de démonstration. Pour de plus amples renseignements, communiquez avec la:

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SOMMAIRE-RECOMMANDATION

Au cours du printemps de 1983, Boise Cascade Canada Ltd. entreprenait un projet avec la province du Nouveau-Brunswick et le gouvernement du Canada en vertu de l'Accord de démonstration des économies d'énergie et des énergies renouvelables (A.D.E.E.E.R.). Le projet comportait deux phases: la phase I consistait en une récolte intégrée de produits forestiers d'exploitation dans des peuplements de faible rendement, tandis que la phase II visait des peuplements exploitables. Dans les deux cas le bois à pâte et les billes de sciage étaient livrés respectivement à l'usine de pâtes et papier et aux scieries locales, et le reste du matériel était transformé en copeaux et livré à l'usine pour alimenter les brûleurs existants de déchets de bois. Ce projet a donc permis de démontrer les aspects économiques et mécaniques d'un système de "récolte intégrée de bois à pâte et de biomasse".

Au cours de la phase I, le bois à pâte et les billes commercialisables des zones de faible rendement étaient récoltés au moyen de systèmes d'exploitation manuelle de bois court et de fûts entiers faisant appel à une main-d'oeuvre intensive. Une fois les résineux marchands extraits au moyen d'une débardeuse ou d'une débusqueuse, tous les arbres et toutes les broussailles sur pied furent abattus de façon directionnelle afin de faciliter leur transformation en copeaux.

Au cours de la phase II, un peuplement exploitable de résineux était récolté en transportant les arbres entiers au bord du chemin,

recueillant ainsi tout le matériel commercialisable. Les résidus d'exploitation et le matériel non commercialisable furent ensuite transformés en copeaux. Pour ce qui est du matériel sur pied, il était abattu, puis déchiqueté sur place ou encore au chemin, où il avait préalablement été transporté en fûts entiers. Un système de conteneurs fut mis en place pour cette phase, afin de transporter le combustible.

Voici les méthodes qui ont été expérimentées pour établir la productivité du déchiquetage du bois dans diverses conditions:

i) le déchiquetage des résidus d'exploitation à la souche (phase I);

ii) le déchiquetage des résidus d'exploitation au bord du chemin (phases I et II); et

iii) le déchiquetage des arbres entiers au bord du chemin (phase I et II).

La phase I du projet no. 2056 s'est terminée vers la fin de février 1984. Il fut alors possible de démontrer que les systèmes de récolte intégrée du bois à pâte et de la biomasse étaient des méthodes viables d'exploitation des zones de faible rendement autrement inexploitables.

La phase II se mit en marche vers la mi-juin, au moment de l'addition d'un système de conteneur pour le transport du combustible. Dès octobre 1984, cette méthode s'était déjà révélée à la fois économique et sûre.

EXECUTIVE SUMMARY

In the spring of 1983, Boise Cascade Canada Ltd. undertook a project with the Province of New Brunswick and the Government of Canada under the Conservation and Renewable Energy Demonstration Agreement, (CREDA). The project was carried out in two phases: Phase I integrated harvesting of primary forest projects in sub-marginal stands and Phase II in operable stands. In both Phases, the pulpwood and sawlogs were delivered to the pulpmill and local sawmills, and the remainder of the materials were chipped and delivered to the already existing hog fuel burners at the mill. By doing so, the economics and mechanics of an "Integrated Pulpwood and Biomass Harvesting" system were demonstrated.

In Phase I, the sub-marginal area was first harvested for merchantable pulpwood or sawlogs by the use of the labour intensive manual shortwood or tree-length systems. Upon extraction of the merchantable softwood by a forwarder or skidder, all remaining trees and brush were directionally felled to facilitate processing by the chip harvester.

In Phase II, an operable softwood stand was harvested by forwarding full trees to roadside, removing all merchantable materials. Upon completion of the harvesting operation, the chipper was used to process the logging residues and unmarketable residuals. The residuals were felled and chipped at the stump or skidded to roadside, full tree, and chipped. A container system was implemented in this Phase, for transporting hog fuel.

To establish chipping productivity under various conditions, the following methods were tried:

i) chipping logging residue at the stump, (Phase I).

ii) chipping logging residue at roadside, (Phase I & II).

iii) chipping full trees at roadside, (Phase I & II)

Phase I of project #2056 was completed by the end of February 1984. By that time it was demonstrated that integrating pulpwood and biomass harvesting systems is a viable treatment for sub-marginal areas that are otherwise inoperable.

Phase II was operational by mid-June with the addition of a container system for transporting the hog fuel. As of October, 1984, this system had proved to be both economical and dependable.

PHASE I: INTEGRATED PULPWOOD AND BIOMASS HARVESTING

INTRODUCTION AND BACKGROUND

Boise Cascade Canada Ltd., Newcastle Division, operates a 200,000 T.P.Y. kraft pulpmill in Newcastle, New Brunswick. With a hog fuel boiler already in place, the Company is actively exploring avenues to further decrease the dependency on imported oil; from some 5 million gallons/year to possibly zero. Any capital investment required to achieve this goal is contingent upon the availability of competitively priced hog fuel in quantities over and above what today is being purchased from local sawmills and woodworking plants.

Initially, the obvious place to look for this extra hog fuel would be from an integrated wood harvesting/hog fuel operation. Located within a 25 km radius of the mill are approximately 1,700 hectares of Crown Land leased to the mill, as well as some company freehold. Currently much of the forest occupying these areas is of very poor quality, having been burned and/or highgraded over a long period of time. However, height/age measurements taken on individual, free growing trees indicates a production capacity of up to 5 m^3 per hectare per year for these sites. To take advantage of this growth potential, these areas should be clear cut and planted. The current species mix and low volumes per hectare makes this economically impossible today, but if some of the wood volumes could be converted into fuel chips and burned in the boilers at the mill, the economics of carrying out a harvesting operation would be quite different. Thus the current low producing acreages would be converted into areas producing up to three times more volume of desirable wood species per year. The short term benefits would be jobs created by the harvesting and chipping operation, and expensive oil would be replaced with reasonably priced hog fuel. The long term benefits would be an improved wood supply close to the mill, which would help to make the mill competitive in the future, and this again would protect and create jobs.

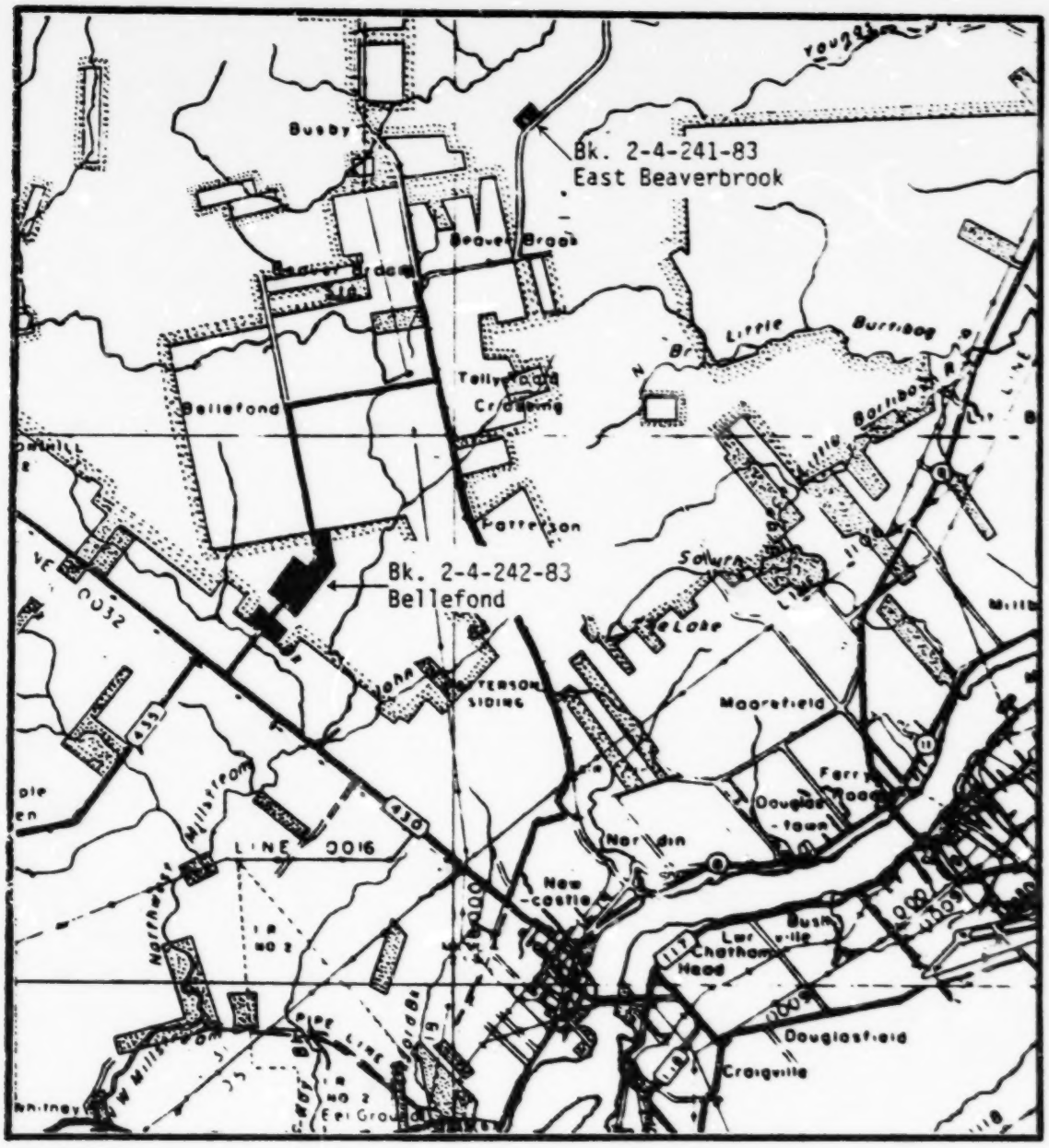
The objectives of project #2056 Phase I were:

i) to reduce our current fuel bill for the mill by substituting hog fuel for oil providing the former is cost-competitive with purchased hog fuel from sawmills;

ii) to determine whether an integrated harvesting system is a feasible treatment for otherwise sub-marginal areas as well as operational areas;

iii) to establish the feasibility of chipping logging residues as a site preparation tool for a variety of stands.

No economic alternatives exist to date for the treatment of sub-marginal stands. With an integrated pulpwood and biomass harvesting system, these areas could be cleaned up and transformed back into high-production softwood stands.


Bk. 2-4-241-83
East Beaverbrook
Bk. 2-4-242-83
Bellefond
Bellefond
Moorefield
Douglastown
Douglastown
Douglastfield
Craigville
Chatham Head
Newcastle
LINE 0016
LINE 0032
PIPE LINE ROAD 6
PIPE LINE ROAD 5
Beaver Brook
Little Burnt Br
Solura
Millstream
Millstream
Millstream

DESCRIPTION OF DEMONSTRATION

Each function of the harvesting operation had been assigned to independent private contractors, namely; i) the cutting and delivery of merchantable softwood and the felling of unmarketable tree species, ii) biomass processing in the form of chipping, iii) the forwarding to roadside of chippable material and iv) the transportation of hog fuel. With the exception of the chipping contractor, all manpower, equipment and materials have been procured locally.

Harvesting (pulpwood & sawlogs): Harvesting operations began June 27, 1983, one month prior to the commencement of biomass processing in block 2-4-242-83 (see figure 1), located 16 kilometers north-west of the Boise mill in Newcastle. The project was designed to produce 8,000 metric tonnes of hog fuel and since that goal had not been reached in block 2-4-242-83, it was necessary to move operations to block 2-4-241-83 for a short time until the production goal was reached. Block 2-4-241-83 is located 28 kilometers north of the mill.

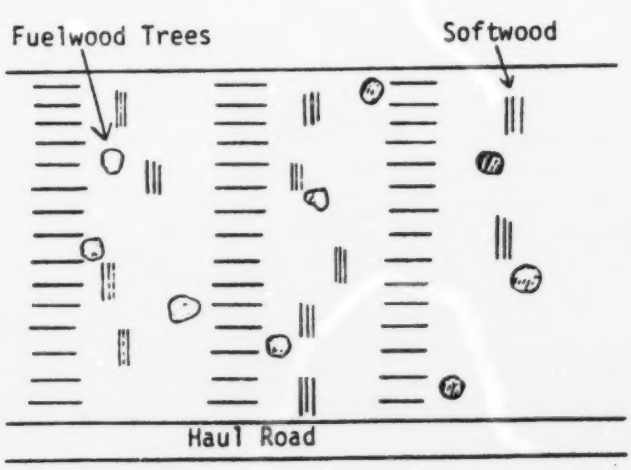
The harvesting of pulpwood and sawlogs was essentially a separate operation from the felling of the unmarketable tree species. All merchantable softwood was first cut by the use of the labour-intensive manual shortwood (i.e., trail cutting) or tree-length systems. Once the merchantable softwood had been removed, the remaining trees and brush were directionally felled to facilitate processing by the chip harvester.

In the manual shortwood system, all merchantable softwood trees are felled, delimbed, bucked and piled at the felling site. Any remaining trees are left standing to be directionally felled after the softwood has been forwarded to roadside. The harvesting pattern (see figure 2) is usually designed so that cutting trails of 15 meters in width and 300 meters in length are arranged perpendicular to the haul road. The resulting rows of brush, in combination with directional felling of the large fuelwood trees, facilitates production for the chipper.

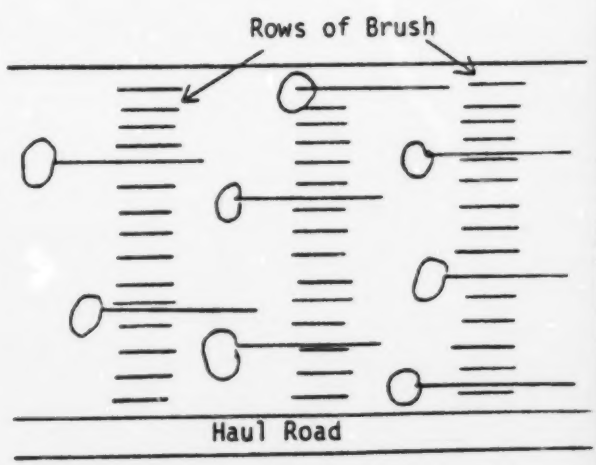
When using the tree-length system in stands of high softwood content, it is necessary that the normal system be modified so that the branches and tops be arranged in rows to simplify retrieval by the chipper. Similar to the manual shortwood system, cutting trails 15 meters in width and 300 meters in length are arranged perpendicular to the haul road (see figure 3). By felling the trees in a herringbone fashion, the brush will be left in rows. The larger fuelwood trees must be directionally felled at right angles to the rows of brush.

The directional felling quality was a very important factor influencing the chipper productivity. It was, therefore, very important to keep that fact in mind during the harvesting operation.

Chipping: The chipping of unmarketable tree species (i.e., Populus tremuloides Michx., Fagus grandifolia Ehrh. and Acer. sp.) as well as harvesting residues (in the form of branches and tops) is carried out by a mobile chipper. The chip harvester (see figure 5) consists of a chipping unit, a power source and a chip bin, all mounted on the chassis of a Kockum SMV21 forwarder. The chipper, manufactured by Bruks AB in Sweden, is a horizontally-fed drum unit which has a maximum tree diameter capacity of 40 centimeters and it is powered by an air-cooled Deutz engine. The chips are blown through a chute into a 17 cubic meter capacity container which is mounted over the Deutz engine. The total loaded weight of the chip harvester is approximately 30 tonnes. In order for the harvester to unload into high-sided trucks, the chip-bin mechanism is designed so that a height of 4.3 meters is reached before any dumping of the hog fuel occurs. The chipper's infeed unit consists of two hydraulically-driven feed rollers which are supplied with hog fuel material by a loader mounted directly behind the forwarder cab. Since the infeed device is located on the right side of the machine, the operator must work to his right at all times (see figure 4). To facilitate productivity it is necessary that all large fuelwood trees (i.e., greater than 10 cm dbh) are felled perpendicular to the chipper's direction of travel, By doing so, the amount of "swing time" for the loader is minimized.



Before forwarding softwood.



After forwarding softwood.

Figure 2. Manual Shortwood System.

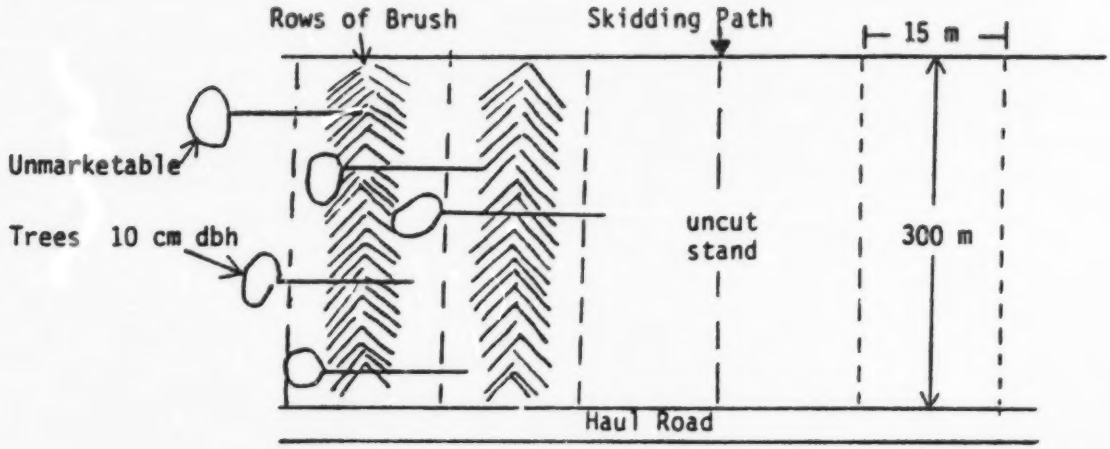


Figure 3. Tree-Length System

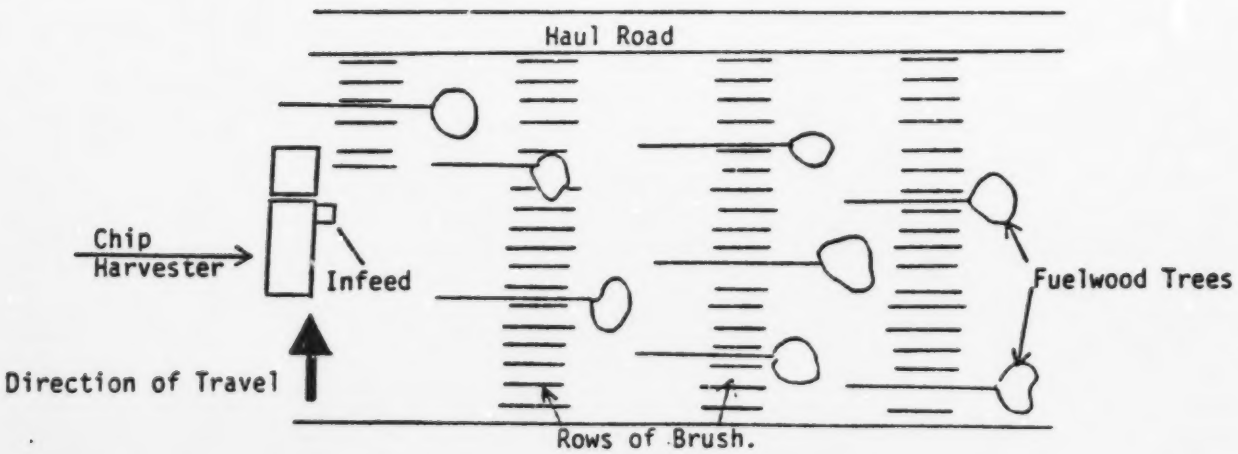


Figure 4. Chip Harvester: Method of Operation.

Upon completion of its load, the chipper travels to roadside where it parks approximately 30 centimeters away from the dump truck. The chip bin is then hydraulically lifted to a height of 4.3 meters whereupon it is tilted, dumping the chips into the truck. Throughout the project, the amount of spillage of hog fuel during the dumping operation has been negligible. The chipper and hog fuel delivery truck operated on a double shift basis throughout most of the project. The felling and forwarding were on single shifts.

Brush Forwarding: The chipper operated for a total of 30 weeks during the course of Phase I, beginning in July, 1983, and ending February 28, 1984. During the last 9 weeks of this phase, a brush forwarder was brought in on an experimental basis to see how much of an increase in productivity the chipper would experience if part of its chipping was done from roadside piles left for it by the brush forwarder. The forwarder itself consisted of a Tree Farmer C6D with a 4.8 m bed and a by-pass grapple. Because unchipped biomass is often characterized by a large volume to weight ratio, the load stakes had to be extended both horizontally and vertically so that the largest possible load could be accommodated. During the weeks in which the forwarder was in operation, the larger fuelwood trees had to be cut into 6 m. lengths so that they could be loaded onto the forwarder bed. This represented no significant loss in terms of the hardwood felling productivity. Because the chipper processed material at a faster rate than the brush forwarder could deliver to roadside, the chipper alternated loads between the cold deck and the stump.

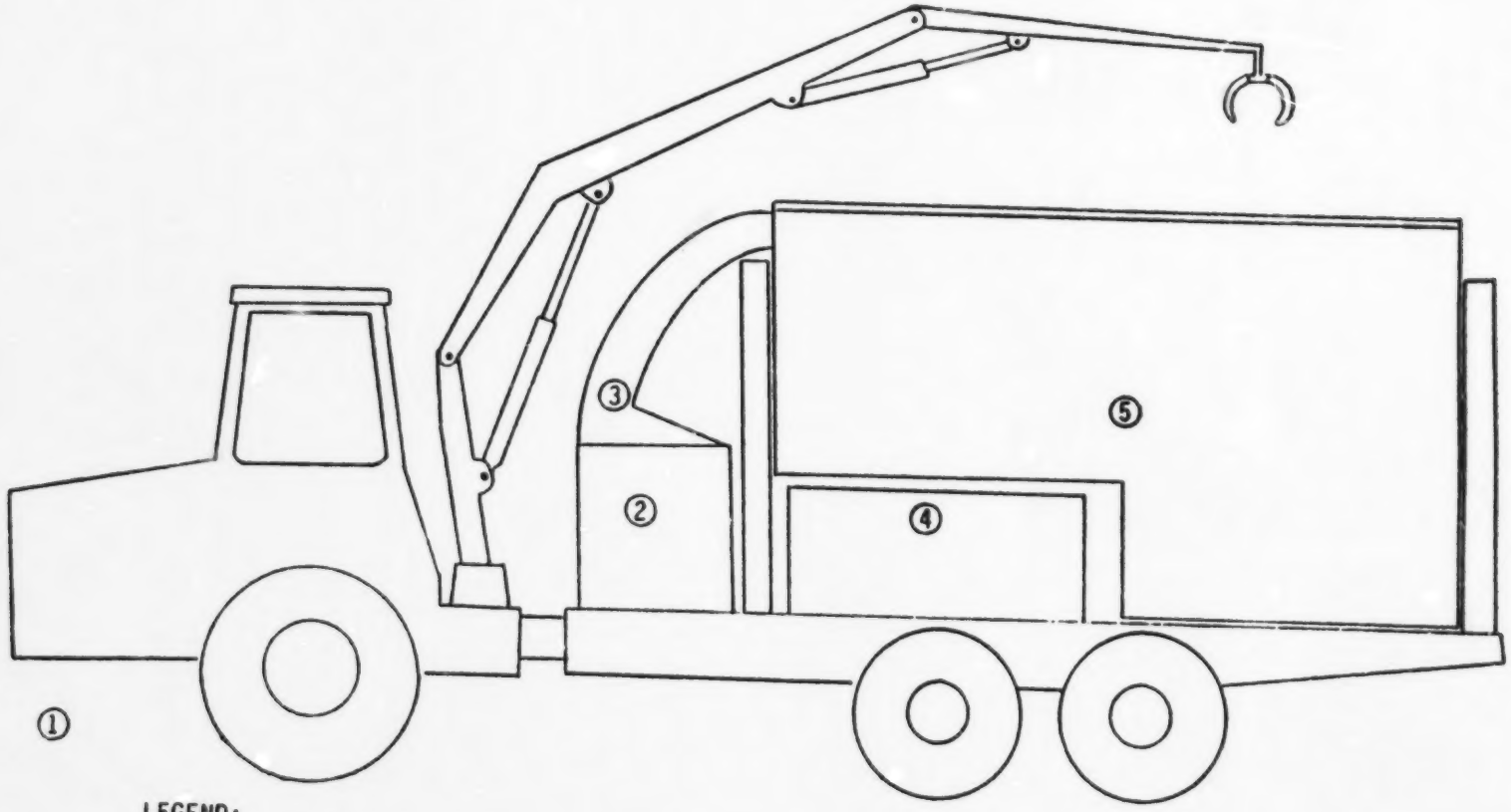
Areas of poor ground strength (i.e., areas which are wet and soft) is another aspect in which the brush forwarder has proven itself to be a very valuable part of the operation. The poorer the ground strength, the lower the productivity of the chipper. The forwarder, being much lighter and more maneuverable than the chipper, can work in these conditions with much less risk of becoming stuck.

Brush forwarding statistics can be found in Appendix V.

Hog Fuel Trucking: The truck used to transport the hog fuel to the mill was a tandem-drive Ford, Model LT800. The inside dimensions of the dump box were 5.5, 2.2 and 2.8 meters for length, width and height respectively. The corresponding volume of 34 cubic meters is sufficient enough to accommodate exactly two full loads from the chip harvester, or an average of 10.28 green tonnes per truck load.

During the project, this single truck was enough to handle the chippers' output due to the fact that the operating areas were in close proximity to the mill. However, if the productivity of the chipper increased much more (i.e., chipper at roadside only), or if the hauling distance increased, this single truck system would not be able to effectively accommodate all the hog fuel produced.

Figure 5. Chip Harvester Schematic.



LEGEND:

1. Kockum SMV 21 Forwarder: 100 KW Volvo Engine.
2. Bruks 1000 CT Drum Chipper.
3. Chip Chute.
4. Chipper Power Source: 160 KW Deutz Engine.
5. Chip Bin (sideways dumping).

Utilization Plots:

A total of three (3) plots each measuring 0.04 ha were randomly laid out in order to measure the utilization obtained by the chipper. In these plots, all tree species were tallied, and heights recorded. Using the tree biomass equations for seven major Maritime species as presented in Enfor Report P-159, the theoretical total biomass volume/plot was then calculated. After the plots had been harvested and chipped, the remaining biomass was weighed, and moisture content recorded.

A table summarizing the results can be found in Appendix VI.

OBSERVATIONS

Phase. I began June 27, 1983, and was completed February 28, 1984. By that time 135 hectares of low volume stands had been cleared, generating 8,006 tonnes of hog fuel, 6,539 m^3 of pulpwood and sawlogs, and 2,356 mandays of employment.

As expected, manday productivity in the harvesting phase was quite low, averaging 5.46 m^3/manday for the manual shortwood system and 4.61 m^3/manday for the tree-length system. The small tree size encountered appears to be the reason for the lower manday productivity in the tree-length system. The manday productivity for the felling of biomass material averaged 6.31 tonnes/manday. Total marketable volume per hectare was 48.43 m^3, plus a hog fuel volume of 59.3 tonnes per hectare. Utilization of the biomass was high with 93.6% of the total available material being removed. The chipper production varied from 4.1 green tonnes/PMH while chipping logging residue in the field, 11.47 green tonnes/PMH while chipping logging residue at roadside and up to 14.46 green tonnes/PMH when chipping full trees at roadside. In combination with the brush-forwarder where the chipper alternated loads between the field and the brush piles at roadside, 7.67 green tonnes/PMH was averaged. The production of brush by the brush forwarder averaged 4.3 tonnes/load and 1.0 loads/PMH. The mechanical availability of the chipper averaged 80.6% for the duration of the project.

A productivity summary of this phase can be found in Appendix IV.

COST/BENEFIT ANALYSIS

Under contractural agreement with CREDA, contributions by the governments and Boise Cascade Canada Ltd. totalled approximately $91,000 and $132,000 respectively, for a total combined cost of $223,000. This corresponds to $27.88 per green tonne of hog fuel produced for Phase I exclusively.

When hog fuel and bunker "C" oil are compared on an equal calorific level, 1 green tonne of hog fuel (at 41.8% moisture content) is equal to 1.52 barrels of oil. It would therefore cost approximately $48.00 in oil to produce an equal amount of energy as $28.00 worth of hog fuel, if oil is purchased at $35.00 per barrel.

Because the chipper removes all logging residues, further site preparation prior to planting is not required. This represents a saving of at least $100/ha at today's site preparation rates.

The energy values and budget costs can be found in greater detail in appendices I, II and III.

CONCLUSIONS

Project #2056 Phase I demonstrated that if a market for hog fuel exists, a combination of harvesting and chipping can be a viable alternative when dealing with stands containing low volumes of marketable species. Current wood costs were minimized by harvesting high quality pulpwood close to the mill, and cost-competitive hog fuel helped to reduce the mill's current fuel bill by providing a substitute for oil. The chipping of logging residues and unmarketable species eliminated the need for any further site preparation. As a result the site will be immediately planted and the new, high-production softwood stand will ensure a reduction in future wood costs.

RECOMMENDATIONS

After having chipped and delivered 8,006 tonnes of hog fuel over eight months, the following changes were recommended in an effort to improve the overall efficiency of the system:

i) Chipper production would be increased by working together with one or more brush forwarders. This was proven with the addition of the brush forwarder to the project, during the last nine weeks of operations, which increased the productivity from 4.1 to 7.67 green tonnes/PMH. The addition of one (1) brush forwarder appears to increase chipper productivity enough to offset the extra cost of forwarding and still lower overall production costs.

ii) Improved directional felling of unmerchantable species would increase the chipper's productivity by making the collection and infeed of material to the chipper much simpler.

iii) Trucking costs would be reduced by increasing the trucking capacity. This could be achieved by using a container system or spotted trailers. These types of systems would also give more flexibility. Using only a truck, if a breakdown occurs the chipper has to stop. With a system such as containers or spotted trailers, the chipper could continue to operate even if the truck was temporarily out of commission. By the same standards, if the chipper suffered mechanical trouble, the truck could continue to haul provided some of the containers or trailers were already loaded and waiting.

iv) Operating the chipper in areas of low ground strength should be avoided. A brush forwarder should be used in these areas.

v) The brush forwarder's productivity can be increased by modifying the bed (i.e., longer load stakes) so that a larger volume per load of chippable material could be accommodated. A self-dumping bed would also increase productivity by decreasing unloading time. A longer boom would serve to give the forwarder an extended reach which would ensure a reduction in positioning time while loading.

vi) A major factor effecting the productivity of the chipper was the moisture content of the chipped material. During the project it ranged from 32.1%, MC on a wet basis at one point in August, to 50.4% at one point in January. Since this variation will have a significant effect upon the chipper's production in terms of green tonnes/PMH, ways should be found to establish a rate scale which allows for fluctuations in the moisture content.

All of these factors could help to improve the integrated harvesting system by increasing the systems productivity, thereby also reducing costs.

PROJECT #2056 PHASE II: HOG FUEL TRANSPORTATION SYSTEM

INTRODUCTION

During Phase I, it was realized that if the productivity of the chipper increased (i.e., chipper at roadside), or if the hauling distance increased, a single truck with only 10 tonnes of payload would not be able to effectively accommodate all the hog fuel produced.

The objective of Phase II was to develop a transportation system using containers, which could be incorporated as a part of an Integrated Pulpwood and Biomass Harvesting System. The container system was designed to enable the whole operation to work effectively, irrespective of:

i) haul distances, (i.e., whether short or long, within reason).

ii) chipper productivity, (i.e., whether at roadside, at the stump or some combination of the two).

iii) breakdowns, (i.e., by providing a buffer zone of loaded and empty containers between the truck and chipper).

DESCRIPTION OF DEMONSTRATION

The container transportation system can be separated into four (4) components:

i) the load exchanger
ii) the truck
iii) the containers
iv) the trailer.

Load Exchanger:

A Hiab-Foco Model LV316 Load Exchanger was purchased from Hiab in Sweden. The load exchanger is a hydraulic arm, which functions in the vertical plane, (i.e., cannot move sideways out of the restricted plane). Figure 6 shows a diagram of the load exchanger in different positions. The six (6) positions indicated on the schematic shows how the arm can be manipulated in the vertical plane. The Model LV316 load exchanger can handle a container of 16 tonnes gross weight and has a dead weight lifting capacity of 8 tonnes.

Positions 1, 2, 3, 4 and 6 in Figure 6 are the sequential motions through which the arm has to go in order to place a container on the ground.

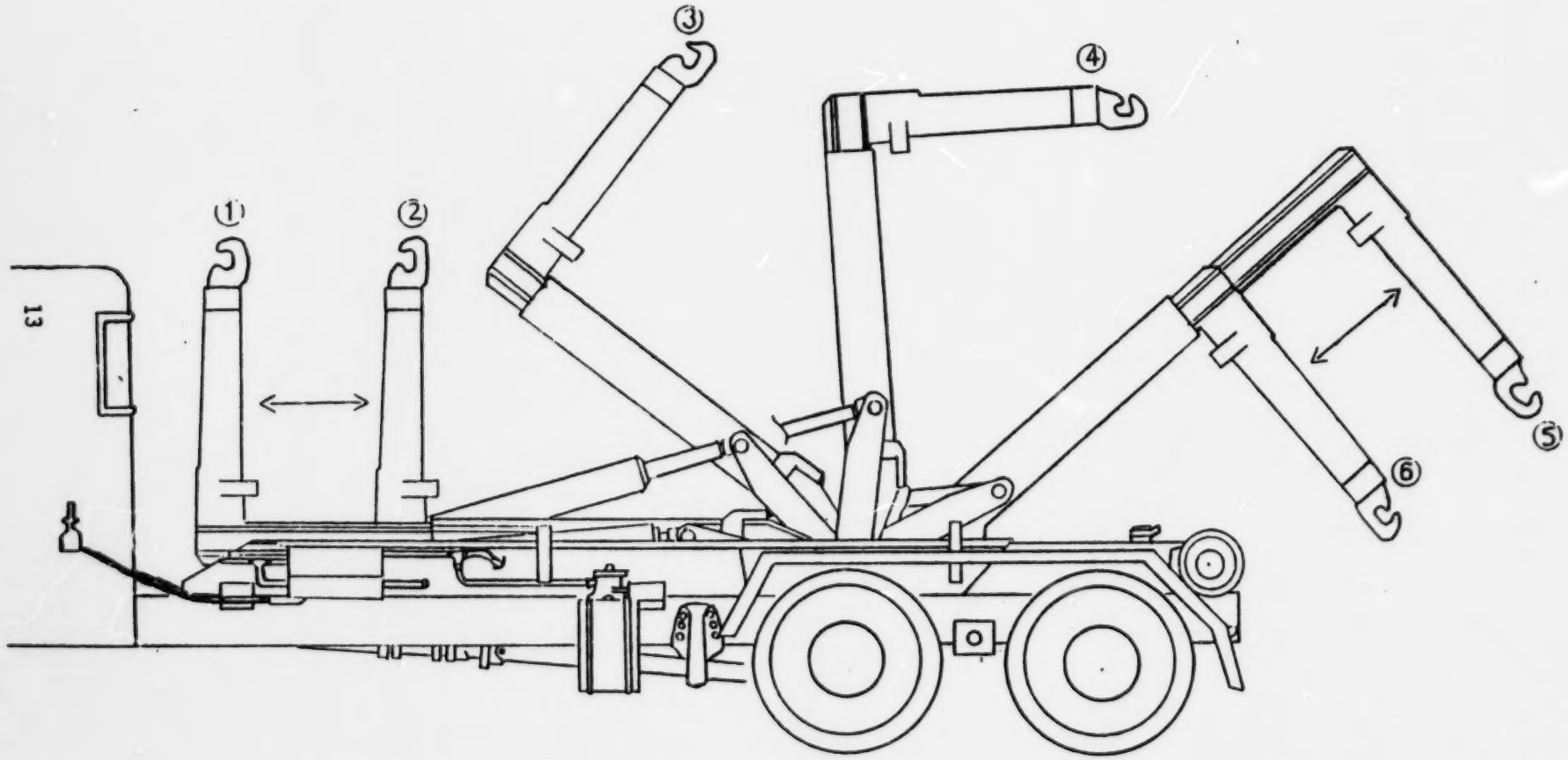


Figure 6. Schematic of the Hiab-Foco LV316 Load Exchanger. (Hiab-Foco Pamphlet.)

Positions 6, 5 or 5, 6, 4, 3, 2, 1 are the steps through which the hydraulic arm moves to pick a container off of the ground and secure it on the truck.

Other specifications relating to the load exchanger can be found in Appendix VII.

Truck:

In June, 1984, the load exchanger was mounted on the back of an International S2600 tandem truck. The truck is equipped with a NTC300 Cummins Diesel engine. Specifications for both the truck and engine can be found in Appendix VIII.

Containers:

Six containers were built by a local firm, Trac Industries, based on modified design specifications of Hiab-Foco Svenska Forsaljnings AB junk containers.

A container consists of two components, a load carrier and a box, (see Figure 7). Figure 8 shows how a load carrier is combined with a box to form a container, which can readily be picked up by any truck with a load exchanger.

The main function of the load carrier is to bear the load of the container and provide the means for the load exchanger to get the container off the ground and onto the truck. The design of the load carrier enables the load exchanger to discharge the load in the container, gravel truck fashion, (see Figure 10).

The box, (Figure 7), was constructed of structural steel channels and angle iron. The sides were lined with 3/4" plywood and the bottom of the box with 2" x 6" planks. The inside dimensions of the box are 2.44 metres x 2.44 metres x 6.10 metres, (h x w x l), which gives the box a volume of 36 cubic metres. The front of the boxes have a ladder and platform, which makes it easier for the operator to round off a load and cover the load with a tarpaulin. The back of the box has two doors that open horizontally and can be pinned back against the sides of the box when the box is being emptied. (See Appendix VII for weight of container.)

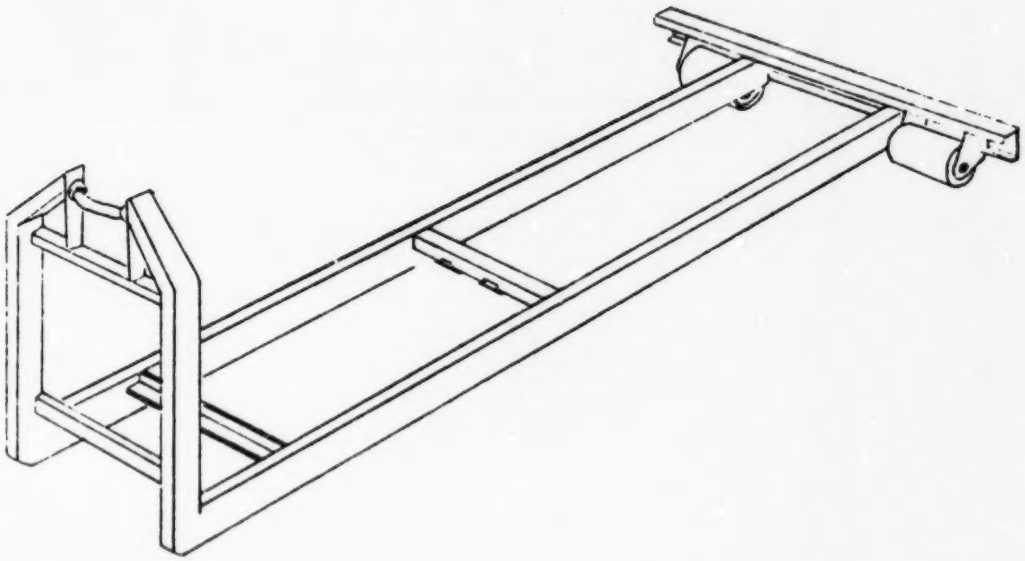


Figure 7.a Load Carrier

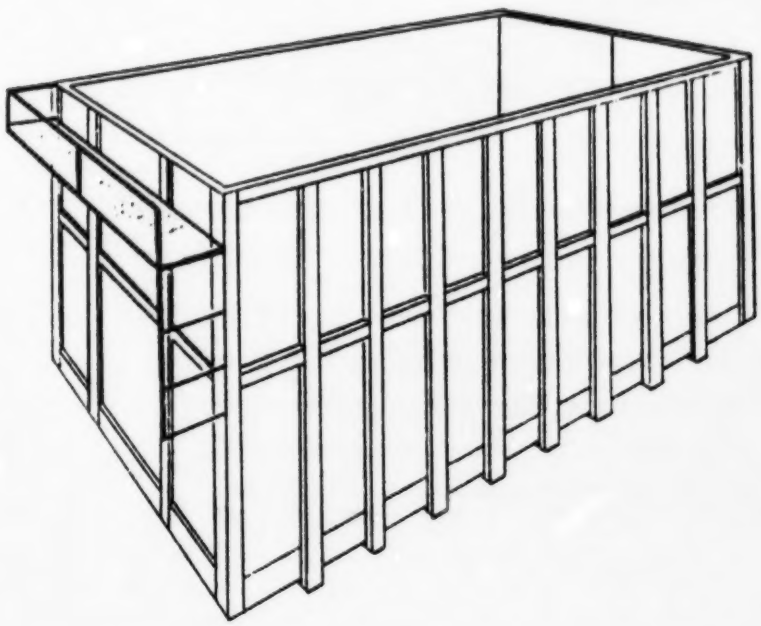


Figure 7.b Hog Fuel Box.

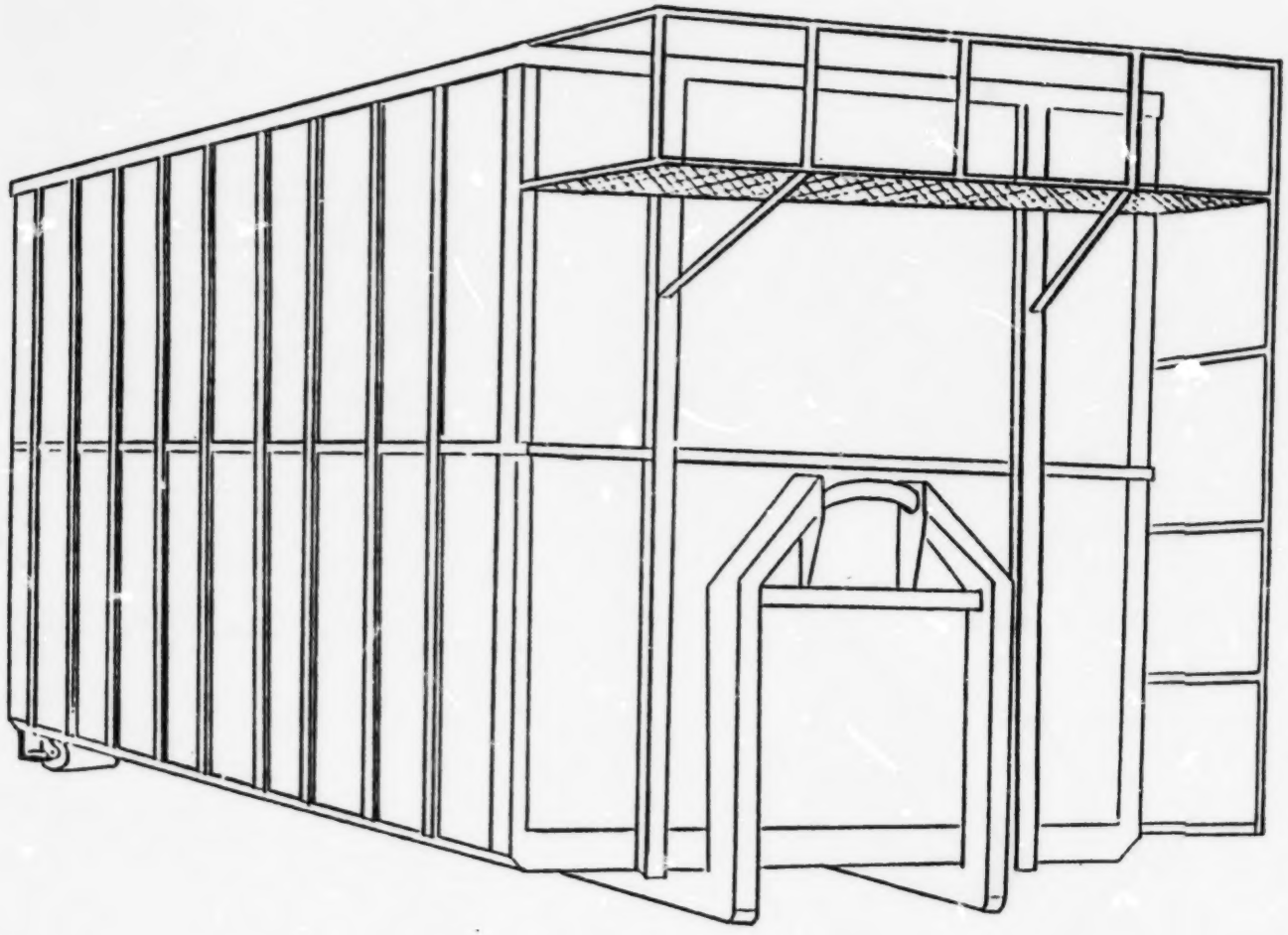


Figure 8 Hog fuel container showing the load carrier and the box combined.

Trailer:

The last component of the container system is a tri-axle trailer, also constructed by Trac Industries of Newcastle, New Brunswick. The trailer has the capacity to carry one container.

The trailer is built with one axle turning on a fifth wheel in the front, and tandem axles in the rear. The truck and trailer are coupled together by a drawbar, that is connected to the front axle of the trailer.

Two turnbuckles with springs attached to them are used to balance the drawbar. By adjusting these turnbuckles, the drawbar can be raised or lowered.

A balanced drawbar allows the operator to connect the trailer to the truck. The locking mechanism on the Pintle Hook, (a quick coupling trailer hitch), is activated when the end of the drawbar slides into the slot of the coupler. The truck operator can connect the trailer, by himself, without getting out of the truck. However, he has to manually reconnect the air hose for the brakes, and fasten the safety chain. (See Appendix VII for weight of trailer).

Mechanics of the transportation system.

During Phase II, the chipper worked at roadside processing full tree hardwood and softwood logging slash. At any one time there were two containers on the truck and trailer, and four on the ground at the chipping site, providing a buffer for both the truck and chipper. If the truck should be delayed for some reasons, the chipper had containers which it could fill. When the chipper had to shut down for repairs, or maintenance, all the containers were filled prior to shutdown, thus allowing the trucking to continue.

Also, the truck and chipper have radios, permitting both operators to know what each other is doing. This communication system eliminates unnecessary waiting time.

In the latter part of the project, both the chipper and truck operated two shifts per day, thus optimizing both the trucking and chipping capacity.

Figure 9 shows the procedures that took place when the truck and trailer returned to the chipping site. Both empty containers were placed on the ground at locations most convenient for the chipper operator. When both empty containers were on the ground, two full containers were loaded, (see Figure 10).

When the truck arrived at the mill, the trailer was disconnected, the tarpaulins removed and the container on the truck was emptied. Figure 11 outlines each step taken to unload the chips at the mill.

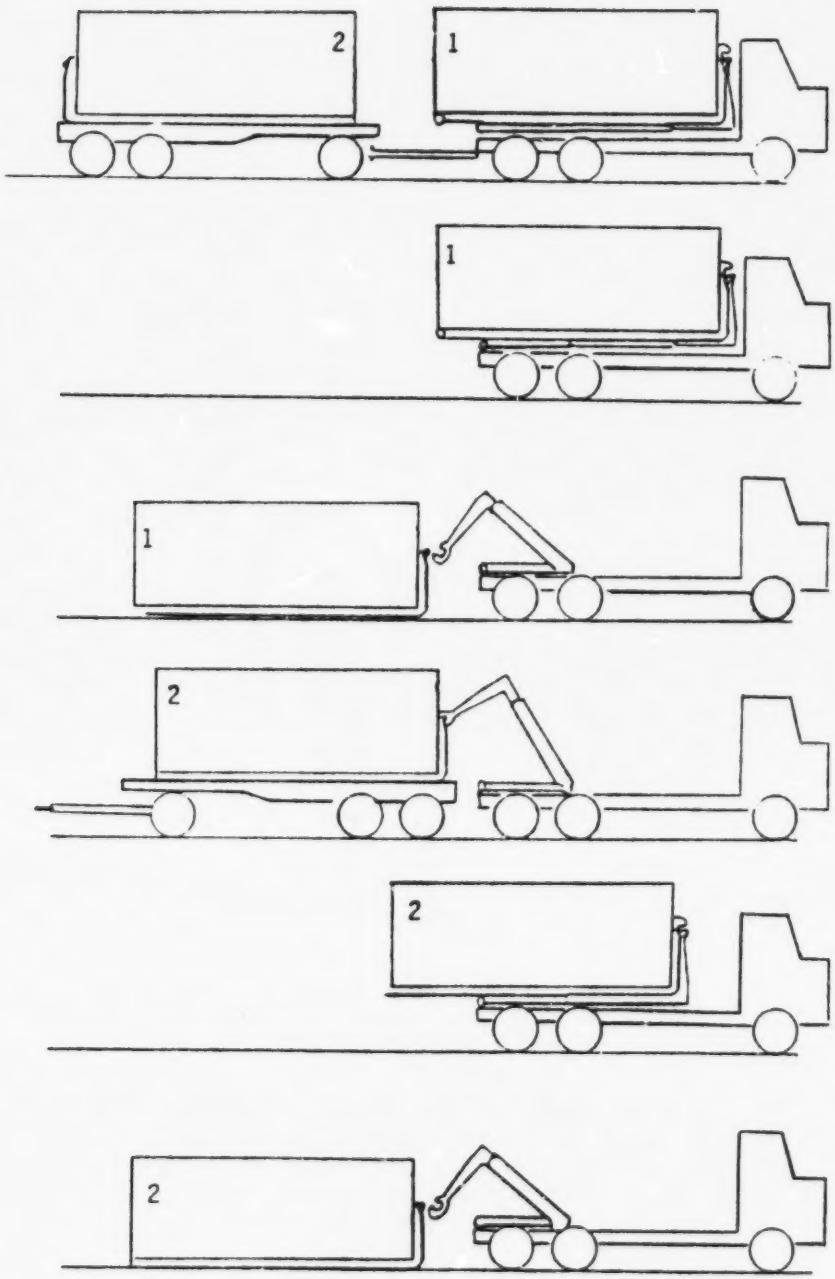


Figure 9 Unloading of empty containers at the chipping site.

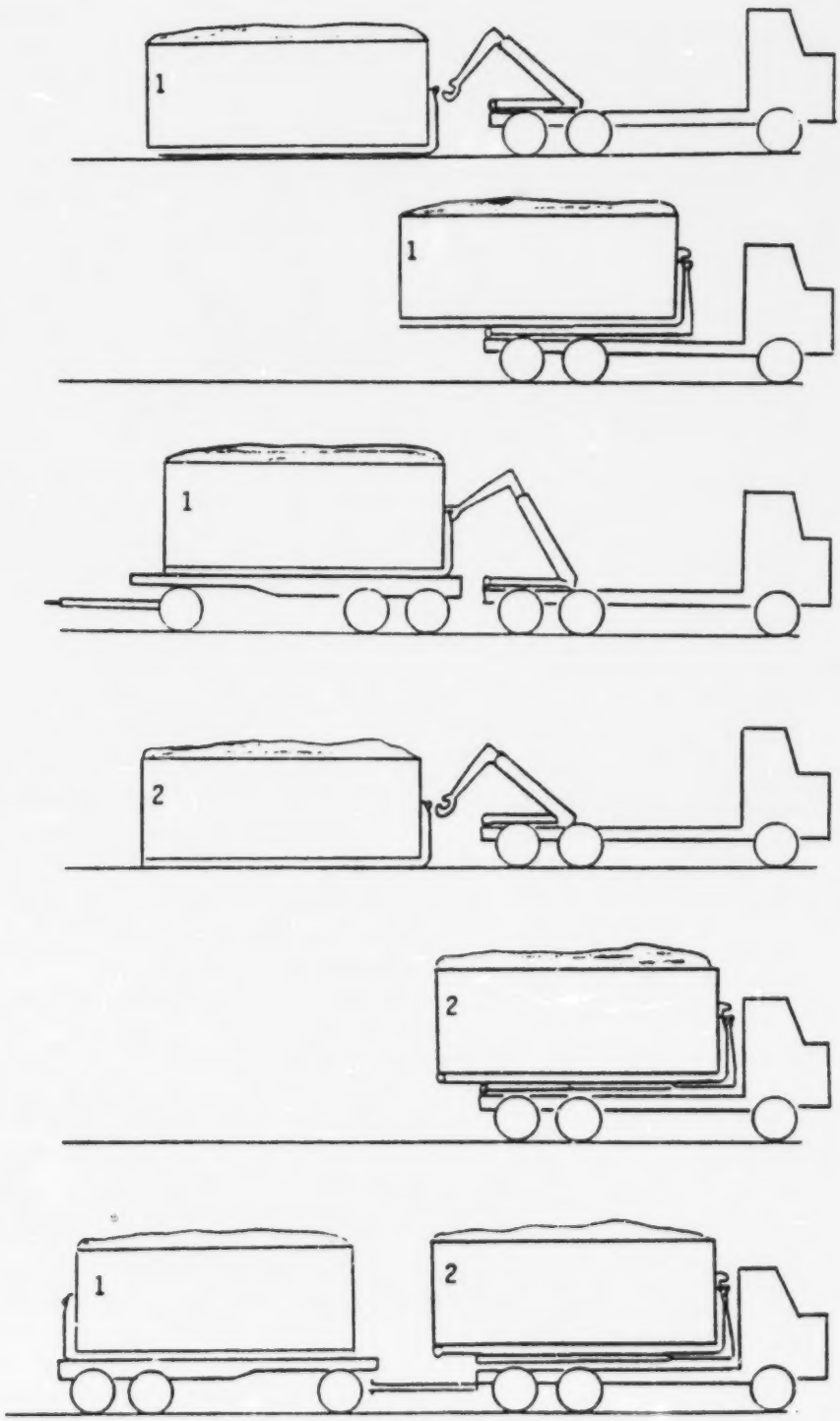


Figure 10 Loading of full containers at the chipping site.

Loading in the woods and unloading at the mill took about the same amount of time, approximately thirty (30) minutes.

OBSERVATIONS

From June 11, 1984 until October 31, 1984, 7,425 tonnes of hog fuel were delivered to Boise Cascade Canada Ltd. mill in Newcastle.

For the first 13 weeks, the chipper processed slash at roadside, and had an average daily production of 60.2 tonnes, (the chipper operated two shifts per day and the truck operated one shift). For the remaining weeks, both the chipper and truck operated two shifts per day, chipping full tree hardwood. For this period, the daily production averaged 102.7 tonnes.

Fluctuating moisture content of the hog fuel produced during the project went from a low of 32%, (wet basis), to a high of 48% (wet basis), with the corresponding amount of hog fuel delivered by the container system per trip ranging from 20 tonnes to 32 tonnes.

COST/BENEFIT ANALYSIS

A $30,000 contribution was provided to subsidize the transportation cost. This phase was based on 7,425 tonnes of hog fuel being delivered to the Boise Cascade Canada Ltd. mill in Newcastle by the end of October.

The Boise Cascade Canada Ltd. mill in Newcastle has no facilities for unloading hog fuel vans, thus, only self-unloading units can be used to deliver hog fuel to the mill.

If the container transportation system is compared to an alternative system, such as live bottom trailers, it can be seen that there is a $3.75/ton difference in favor of the container system, (see Appendix IX).

This difference occurs when both systems are operating approximately 80 km from the mill and only making two trips in a twelve-hour shift. If the chipping operation were closer to the mill, (thus more tons could be delivered per day), the difference in delivery costs of the system would be much smaller, but the container system would still be the more economical.

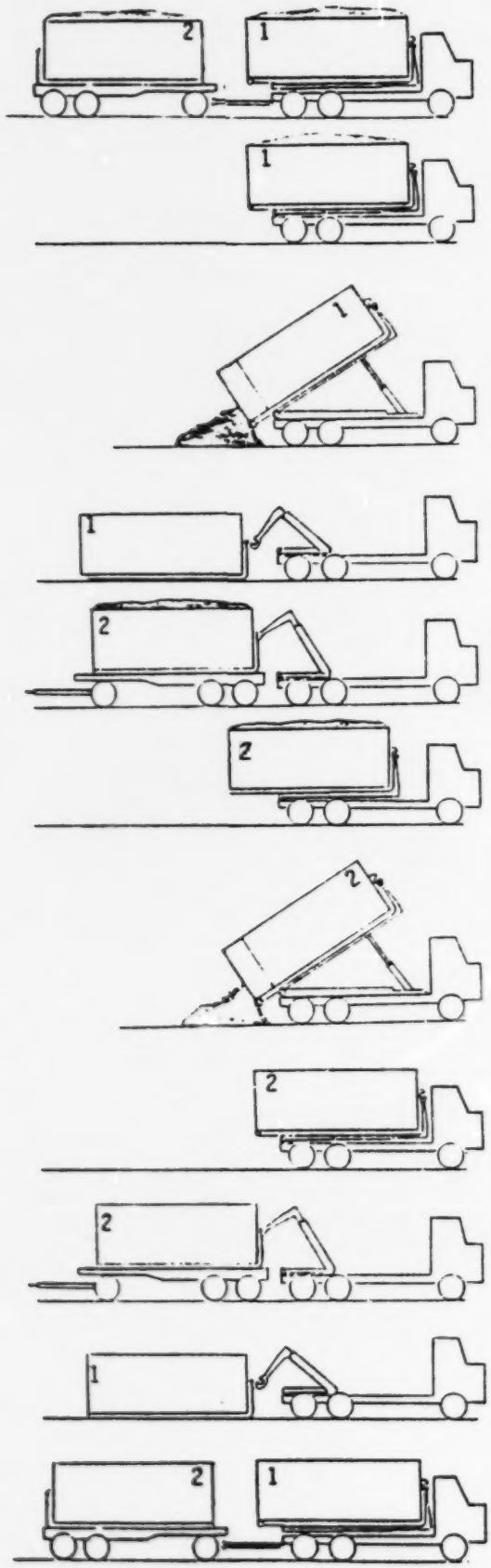


Figure 11. Unloading hog fuel at the mill.

CONCLUSIONS

When compared with available systems for delivering hog fuel to the Newcastle mill, the container system has proven itself to be both economical and dependable. The individual container size has been satisfactory, giving a legal payload under most circumstances. The exception being when the moisture content of the hog fuel was lower than 30-35% (wet basis), resulting in a poor utilization of the trucks carrying capacity. It provided the needed flexibility between the chipping unit and the truck and was found to be effective regardless of the trucking distances encountered during this project (up to 100 km).

RECOMMENDATIONS

The following recommendations are suggested as further improvements for the Biomass Chipping and Transportation System:

i) Payment to chipper and trucker on a volume basis (m^3) rather than on a weight (ton) basis. (Fluctuations in moisture content made it very frustrating for all parties to try to establish fair rates per ton).

ii) The chipper production is maximized when the chipper is operating at or near roadside. However, indications are that skidders or forwarders might not be the most economical method of bringing chippable material to roadside. A clambunk skidder with a felling head should be tried.

iii) The dolly-type fifth wheel on the trailer should be replaced with a dolly-type turntable, for better control of the trailer.

iv) It appears that dry chips (30%-40% MC wet basis) should be produced rather than wet chips (50% MC wet basis). This can be achieved by letting the slash and full trees dry out prior to chipping. If this is the case, ways should be found to increase the truck's payload, such as increased container size, or one additional container on the trailer.

APPENDICES

APPENDIX I

BIOMASS ENERGY VALUE

1. Assumptions

i) Boiler Efficiency: Oil - 83%

Hog Fuel - 70%

ii) 1 dry tonne hog fuel: 20.193 Giga Joules (GJ)

*1 green tonne hog fuel @ 41.8% moisture content = 10.672 GJ (see Appendix II)

iii) 1 barrel Bunker "C" Oil: 6.508 GJ

2. Chip Harvester Hog Fuel

1 green tonne - (70% efficiency) 10.672 $\left(\frac{\text{GJ}}{\text{green tonne}}\right)$

- 7.47 GJ/green tonne available to be converted into steam.

3. Bunker "C" Oil

1 barrel - (83% efficiency) (6.508 GJ/bbl)

- 5.402 GJ/barrel available to be converted into steam.

4. Oil Equivalent of Hog Fuel:

1 green tonne hog fuel - $\frac{7.47 \text{ GJ/green tonne}}{5.402 \text{ GJ/barrel}}$

- 1.38 barrels

5. Value of Hog Fuel

1 green tonne hog fuel - $\left(1.38 \frac{\text{bbl. oil}}{\text{green tonne}}\right)$

- $48.40/green tonne

($35.00/bbl. oil)

APPENDIX II

CONVERSION FACTORS

IMPERIAL RELATIONSHIPS

1 imperial gallon Bunker "C" oil	-	176,376 BTU
1 barrel oil	-	34.9726 imperial gallons
1 barrel oil	-	6,168,000 BTU
1 dry pound hog fuel	-	8,700 BTU
1 dry ton hog fuel	-	17,400,000 BTU

METRIC CONVERSION FACTORS

1 BTU	-	1,055 Joules (J)
1 barrel oil	-	6.508×10^9 Joules
	-	6.508 Giga Joules (GJ)
1 dry tonne hog fuel	-	20.193×10^9 Joules
	-	20.193 GJ

FOR MOISTURE CONTENT - 41.8%

1 green tonne hog fuel - (1 - 0.418) (20.193 GJ/dry tonne)

- 11.752 GJ

Minus energy required to vapourize the water 1BTU to heat 1lb. of water by 1° F (assume wood at 70° F)

= (212 - 70°) (2200) (0.418)

= 130,583 BTU

Plus Latent heat of vapourization

= (970 BTU/lb) x (2200 x 0.418)

= 892,012 BTU

Total = 130,583 + 892,012

= 1,022,595 BTU (1.08 GJ)

1 Green tonne hog fuel = 11.752 - 1.08

= 10.672 GJ

APPENDIX III

BUDGET REVIEW

Expenditures By Item	Total Expenditures	
PHASE I		
Felling of Unmarketable Species	$ 28,007.62	
Biomass Chipping	103,927.31	
Chip Transportation Costs to Newcastle Mill	54,234.45	
Monitoring Expenses	28,760.14	
Road Maintenance	3,806.20	
Other Charges	5,044.50	
TOTAL COSTS	$ 223,780.22	
Deduct Cost Absorbed by Pulpmill	$(132,111.00)	
Sub-total		$ 91,669.22
PHASE II		
Chip transportation cost to Newcastle mill (8,167 tons)	$ 63,754.00	
Cost absorbed by mill	$ (33,754.00)	
Sub-total		$ 30,000.00
TOTAL		$ 121,669.22

APPENDIX IV
CHIPPER PRODUCTIVITY SUMMARY

Week	Productivity (green tonnes) PMH	Productivity (dry tonnes) PMH	Moisture Content %	Cover Type	Stand Conditions (dry tonnes) ha	Ground * Strength	Felling Quality
1	3.90	2.54	34.9	SH	55.35	3	Poor
2	3.67	2.35	35.9	SH	55.35	3	Poor
3	3.50	2.23	36.3	SH	55.35	3	Poor
4	4.30	2.83	34.1	SH	55.35	3	Poor
5	4.10	2.78	32.1	S	58.14	3	Good
6	4.85	2.98	37.9	HS	41.30	2	Good
7	5.17	3.20	38.2	HS	41.30	2	Good
8	5.68	3.37	40.7	HS	41.30	2	Good
9	5.60	3.23	42.3	HS	41.30	2	Good
10	3.93	2.66	32.3	S	43.96	3	Poor
11	3.78	2.32	38.7	S	43.96	3	Poor
12	4.58	2.67	41.6	S	43.96	2	Fair
13	4.69	2.63	43.9	S	43.96	2	Fair
14	4.58	2.70	41.0	HS	41.30	2	Fair
15	4.16	2.53	39.3	HS	41.30	2	Fair
16	3.73	2.18	41.5	HS	41.30	3	Poor
17	3.77	2.32	38.5	SH	35.70	3	Poor
18	3.49	1.99	43.1	SH	55.35	4	Poor
19	4.34	2.52	41.9	SH	55.35	2	Good
20	4.55	2.52	44.5	SH	** 9.39	1	Good
21	4.27	2.28	46.6	SH	** 9.39	1	Good
22***	4.45	2.57	42.2	SH	** 9.39	1	Good
23***	6.55	4.13	36.9	HS	62.96	1	Good
24***	6.49	3.46	46.7	HS	62.96	1	Good
25***	8.34	4.14	50.4	HS	62.96	2	Good
26***	6.96	3.52	49.4	HS	62.96	2	Good
27***	7.61	3.90	48.8	SH	41.34	3	Good
28***	7.52	3.82	49.2	SH	41.34	3	Good
29***	7.70	4.02	47.8	HS	71.55	2	Good
30***	7.84	4.13	47.3	HS	71.55	2	Good

* FERIC Ground Strength Classification: Consists of 5 clases with number 1 being the strongest and number 5 the weakest.

** Area burnt, therefore, stand conditions data is not accurate.

*** Brush forwarder in operation.

APPENDIX V

BRUSH FORWARDER SUMMARY

	Test #1	Test #2	Test #3	TOTAL
Tonnes	813.5	358.95	316.55	1,499.0
Forwarder Loads	179	84	81	344
Hours (PMH)	162.7	92.3	90.0	345.0
Tonnes/Load	4.54	4.27	4.03	4.36
Loads/Hour (PMH)	1.10	0.91	0.90	1.00
Tonnes/Hour (PMH)	5.00	3.89	3.63	4.36

APPENDIX VI

SUMMARY OF UTILIZATION PLOT DATA

Dbh Class (cm)	SPECIES (dry tonnes) B.Fir	Spruce	R.Maple	T. Aspen
2	--	.02	--	--
4	.02	.08	.08	--
6	.03	.25	.13	--
8	.04	.34	.15	.01
10	.18	.45	.10	.02
12	.06	.51	.14	.02
14	.08	.69	.15	--
16	.04	.69	--	.14
18	.05	.41	.18	.38
20	--	--	--	.25
22	--	.29	--	.16
24	.07	.09	--	.58
26	--	.21	--	.48
28	.16	.11	--	.29
30	--	--	--	--
32	--	--	--	--
34	--	.16	--	--
36	--	--	--	--
38	--	.20	--	--
40	--	--	--	--
TOTAL DRY TONNES BY SPECIES	0.73	4.50	0.93	2.33

Available chippable biomass on plots: 8.50 dry tonnes
: 13.74 green tonnes

Total Area of plots : .12 ha.

Remaining biomass on plots : .88 green tonnes

Utilization: $1 - \frac{.88 \text{ green tonnes}}{13.74 \text{ green tonnes}} = 93.6\%$

APPENDIX VII

CONTAINER SYSTEM SPECIFICATION

Load Exchanger

Length	5.2 metres
Weight	2,250 kg
Max. Oil Pressure	210 Kp/cm²
Oil pump	11.0 litres/minute

Truck:

Weight	8,900 kg

Container:

Weight	2,250 kg

Trailer:

Weight	6,125 kg
Length	6.7 metres

Total weight of the truck, trailer, and two (2) empty containers = 21,775 kg
OR
48,000 lbs.

APPENDIX VIII

TRUCK ENGINE SPECIFICATIONS

Specifications: Cummins NTC 300 Diesel Engine

	Imperial	Metric
Power rating	300 hp	224 kW
Rated speed	2,100 rpm	2,100 rpm
Peak torque (@ 1300 rpm)	1,000 lb-ft	1,356 N.m
Number of cylinders	6	6
Displacement	855 cu in	14 L

APPENDIX IX

COST BENEFIT ANALYSIS

Container System:

- truck, trailer, load exchanger, six (6) containers.
- payload 27 tonnes per trip.

Live Bottom System:

- truck, three (3) live bottom trailers.
- payload 31 tonnes per trip.

DATA FOR ANALYSIS

Operating days per year	210
Hrs/Shift	12
Shifts/Day	1
Life of machines (hours)	10,080
Service & repair cost (% of unit cost)	75%
Utilization	100%

	Container	Live Bottom
System Purchase Cost ($)	140,000	265,000
Residual Value ($)	28,000	53,000
Average Investment ($/year)	98,000	185,500
Capital Recovery Deprec. ($/year)	43,429	82,206
Total Variable Cost ($/year)	47,057	73,035
Total Fixed Cost ($/year)	47,166	87,850
Total Operator Cost ($/year)	25,200	25,200
Total Annual Cost	119,423	186,085
Total Cost/Shift	569	886
Tonnes Delivered/Shift	54	62
Cost/Tonne	10.54	14.29